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Upper Middle to lower Upper Ordovician chitinozoans and conodonts from the Bliudziai-150 core, southern Lithuania

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Abstract: Integration of chitinozoan and conodont biozones is based on detailed collections from the Bliudziai-150 well, southern Lithuania that penetrated upper Darriwilian – lower Sandbian sedimentary carbonate rocks. The strata accumulated at the southeastern side of the Livonian Tongue and represent the transition from shallow shelf facies of the Lithuanian shallow-water shelf facies belt to the deeper-water shelf facies belt. Systematically collected and closely spaced samples of the carbonates from the Bliudziai-150 core yielded both chitinozoans and conodonts in abundance. The chitinozoans are assigned to the *Laufeldochitina striata*, *Laufeldochitina stentor*, *Angochitina curvata*-*Armoricochitina granulifera*, *Lagenochitina dalbyensis*, *Belonechitina hirsuta* and *Spinachitina cervicornis* chitinozoan biozones and the conodonts to the *Pygodus serra* Zone (with three subzones), *Pygodus anserinus* Zone (with two subzones) and the three subzones of the *Amorphognathus tvaerensis* Zone.

The fossils are clearly of Baltoscandian affinity and the integrated results support existing knowledge concerning the biostratigraphy of the two groups in Baltoscandia. Thus, the studied interval is confidently assigned to the Lasnamägi, Uhaku, Kukruse and Haljala regional stages of the East Baltic regional chronostratigraphical scheme, corresponding to the global upper Darriwilian – lower Sandbian stages (Middle to Upper Ordovician). International correlation of the chitinozoan and conodont succession is presented and the position of the base of the international Sandbian Stage is placed at 1380.00 m in the BI-150 core. A horizon marked by multiple discontinuity surfaces represents the base of Kegel depositional sequence and coincides with the appearance of *Armoricochitina granulifera*, *Angochitina curvata*, *Lagenochitina dalbyensis* and *Baltoniodus gerdae* in the BI-150 core.

Keywords: Chitinozoans, Conodonts, Ordovician, Biostratigraphy, Lithuania.

Introduction

Chitinozoans and conodonts are two well-established microfossil groups that are used extensively for biostratigraphical evaluations and correlations, especially in the upper Middle to Upper Ordovician of the Baltoscandian region of northern Europe (e.g. Bergström 1971; Dzik 1978; Grahn 1984; Nölvak and Grahn 1993; Nölvak and Bauert 2006; Grahn and Nölvak 2010; Zhang 1998; Saadre *et al.* 2004; Viira 2008, 2011; Viira *et al.* 2006; Hints *et al.* 2012; Männik and Viira 2012). This paper presents the faunal succession from the little known Bliudziai-150 core section in southern Lithuania located on the eastern flank of the Livonian Tongue (Laskov *et al.* 1981; Laskovas 2000). The study is based on direct evidence and high-resolution integration of chitinozoan - conodont biostratigraphy for upper Middle and lower Upper Ordovician. It provides close ties with the Ordovician chitinozoan and conodont biozonations characteristic for the regional Lasnamägi to Haljala stages and correlation to the international Middle to Upper Ordovician series boundary in carbonate facies.

Geological setting, stratigraphy and material

During the Ordovician the Baltoscandian platform, west of present-day Moscow, was covered by an intracratonic sea and mostly carbonate rocks were deposited in this large area. The Ordovician epicontinental sea was connected to the offshore deeper-water environment with fine-clastic sediments in the northwest and southwestern Caledonides (Fig. 1). The Ordovician succession of the study area accumulated on the eastern flank of the Livonian Tongue composed of

marine limestone, marl, minor siltstone and organic-rich shale that were deposited on the shelf during several transgressive-regressive cycles and in a shallow to moderately deep-water setting.

The Bliudziai-150 well (N55°15'16.056", E22°57'59.976") was drilled near Šimkaičiai in southern Lithuania, approximately 165 km west to northwest of Vilnius (Fig. 1). The investigated 22 m long interval (1391 to 1369 m; Fig. 1) constitutes the Daugavpils Group, subdivided into three formations: in ascending order, the Vyžūnai (1391.91 to 1383.15 m), Krastai and Kriaunos formations (1383.15 to 1973.90 m) and the two stratigraphically succeeding Sartai and Šventupys formations (from 1373.90 m), which are the two lower formations of the Mezciwys Group (Laskovas 2000; Fig. 1). The boundary between the Kriaunos and Sartai formations is prominent and the series of closely spaced discontinuity surfaces with phosphatic impregnations is characteristic for the upper beds of the Kriaunos Formation. The numerous discontinuity surfaces indicate an irregular character of sediment accumulation.

The 53 closely spaced to nearly bed-by-bed samples were collected and processed for both chitinozoans and conodonts in the interval ranging from 1390.92 m to 1369.07 m, covering the Lasnamägi, Uhaku, Kukruse and Haljala regional stages. All samples were productive for conodonts, but the samples from the lowermost (1390.92 m to 1390.07 m) and middle portions (1387.89 m to 1384.25 m) of the Vyžūnai Formation consisting of red to interbedded green limestone were barren of chitinozoans.

Biostratigraphy of the Bliuziai-150 core

The chitinozoan fauna is of high diversity in terms of number of species, but the degree of preservation is poor to moderate (i.e. the observed chitinozoan vesicles are rather brittle

and often broken into pieces). The conodont fauna is moderately diverse, and of reasonable abundance. The CAI value is approximately 1.5 of Epstein *et al.* (1977), and up-section the preservation declines from fine to good (often broken specimens). Altogether 47 chitinozoan species from 16 genera and 23 genera and 41 conodont species have been identified from the studied upper Darriwilian – lower Sandbian succession. The ranges of the biostratigraphically significant chitinozoan and conodont species are given in Figure 1 and illustrated in Figures 2 and 3.

REPOSITORY: All illustrated chitinozoan specimens are hosted at Institute of Geology at Tallinn University of Technology (GIT nos. 726-1 – 726-10). The figured conodont specimens are kept at the micropaleontological collections of the Natural History Museum of Denmark, University of Copenhagen, Denmark (MUGH nos. 31429–31453).

Chitinozoan biozones

The chitinozoan taxonomy used here follows that of Paris *et al.* (1999) and the chitinozoan zones are after Nölvak and Grahn (1993). Chitinozoans with short temporal ranges are well known from the Darriwilian–Sandbian succession of the Estonian and Swedish sections of Baltoscandia (e.g. Grahn 1984; Nölvak *et al.* 1999; Nölvak and Bauert 2006; Grahn and Nölvak 2010; Tammekänd *et al.* 2010).

The lowest chitinozoan zone in the studied Bliudziai-150 section is the *Laufeldochitina striata* Zone (interval 1389.91 to 1380.70 m). However, the *Conochitina clavaherculi* and *Conochitina tuberculata* Subzones of Nölvak and Grahn (1993) have not been recognized due to the poor preservational potential of chitinozoans in oxidized red limestone (e.g. Fig. 1). Other

species, characteristic to the *Laufeldochitina striata* Zone, are *Tanuchitina tallinnensis*, *Belonechitina pelliifera* and *Cyathochitina sebyensis*.

The *Laufeldochitina striata* Zone is directly followed by the *Laufeldochitina stentor* Zone, which is recorded from the Krastai-Kriaunos formations. The characteristic chitinozoan species for the *Laufeldochitina stentor* Zone includes (in order of FAD) *Eisenackitina rhenana*, *Conochitina savalaensis*, *Belonechitina intonsa*, *Conochitina viruana*, *Laufeldochitina* aff. *striata*, *Cyathochitina giraffa* and *Conochitina tigrina*. The Sartai and Šventupys formations comprise four temporally short chitinozoan zones (Nõlvak and Grahn 1993) all of which have been established in the Bliudziai-150 section. *Angochitina curvata* and *Armoricochitina granulifera* are the oldest zonal chitinozoans, both of which are recorded in one sample and thus form a the joint *A. curvata* - *A. granulifera* chitinozoan Zone in the Sartai Formation. The following *Lagenochitina dalbyensis* Zone includes the temporally limited species *Belonechitina jaanussonii*. The stratigraphical extent of the *Belonechitina hirsuta* Zone is not well confined in this section as the zonal species is recorded in only one sample. The *Spinachitina cervicornis* Zone is the uppermost chitinozoan zone recorded in the Bliudziai-150 core.

Conodont biozones

The conodont zones of Bergström (1971, 1983, 2007a, b) with additions by Dzik (1978, 1994) and Zhang (1998) are here used as reference. The conodonts are amber coloured. The fauna is clearly of Baltoscandian affinity i.e. belonging to the North Atlantic conodont province typical of Baltica.

The investigated Ordovician deposits of the Bliudziai-150 core are assigned to the *Pygodus serra* Zone with the *Baltoplacognathus reclinatus*, *Baltoplacognathus robustus* and *Eoplacognathus lindstroemi* subzones (the *Yangtzeplacognathus foliaceus* Subzone has not been investigated in this study), the *Sagittodontina kielcensis* and *Amorphognathus inaequalis* subzones of the *Pygodus anserinus* Zone and *Baltoniodus variabilis*, *Baltoniodus gerdae* and *Baltoniodus alobatus* subzones of the *Amorphognathus tvaerensis* Zone.

Pygodus serra is recorded from 1389.19 m to 1384.55 m and within the Vyžūnai Formation, but it is probable that the full range of this taxon was not detected here. *Baltoniodus prevariabilis* and *Sagittodontina kielcensis* are common associated species. First occurrence (FO) of *Triangulodus alatus* is at 1390.70 m and ranges continuously to 1388.12 m, and last occurrence (LO) is at 1381.48 m. *Periodon aculeatus* is only present in the lowest sample. These taxa are associated with *Cornuodus longibasis*, *Dapsilodus viruensis*, *Decoriconus pesequus*, *Costiconus ethingtoni*, *Drepanoistodus* spp. A, *Drepanoistodus? balticus*, *Drepanodus arcuatus s.l.*, *Drepanodus cf. D. robustus*, *Oslodus semisymmetricus*, *Panderodus sulcatus*, *Protopanderodus graeai* and *Semiacontiodus longicostatus*.

The *Baltoplacognathus reclinatus* Subzone is the second lowest recorded subzone of the *Pygodus serra* Zone; it extends from 1390.92 m to 1388.40 m. Few specimens of *Yangtzeplacognathus foliaceus* from the underlying *Yangtzeplacognathus foliaceus* Subzone are observed in the lowest investigated sample (i.e. 1390.92 to 1390.76 m). The following *Baltoplacognathus robustus* Subzone is recorded from 1388.40 m to 1384.98 m within the Vyžūnai Formation (Fig. 1). This same interval is characterized by the consistent presence of *Triangulodus alatus* and FO of *Protopanderodus varicostatus* is at 1388.40 m. The FAD of *Eoplacognathus lindstroemi* is at 1384.79 m and it ranges up to 1382.71 m, meaning that the *Eoplacognathus lindstroemi* Subzone is recorded in the top of the Vyžūnai Formation and the lower part of the

Krastai Formation. The FAD of *Eoplacognathus lindstroemi* is accompanied by *Yangtzeplacognathus protoramosus* (late form) and *Phragmodus polonicus*, both of which are present only at this single level.

The FAD of *Pygodus anserinus* is at 1384.25 m and LAD at 1379.05 m. The former level marks the base of the *P. anserinus*-*Sagittodontina kielcensis* Subzone. The transition from *Baltoniodus prevariabilis* to *Baltoniodus variabilis* is observed in this subzone. *Protopanderodus* cf. *liripipus* appears at 1382.07 m, which is slightly above the base of the Krastai Formation. The fauna continues unchanged until 1378.87 m i.e. to the formational boundary of the Krastai and Kriaunos formations. The *Sagittodontina kielcensis* Subzone extends from the base of the *Pygodus anserinus* Zone at 1384.25 m to FAD of *Amorphognathus inaequalis* at 1381.25 m.

The base of the *A. inaequalis* Subzone is at 1381.25 m. The species is consistently present in the succeeding samples, but specimens are mostly small. *Sagittodontina kielcensis* disappears at the same horizon. *Scabbardella altipes* is newcomer at 1379.42 m i.e. within the uppermost portion of the subzone.

Amorphognathus tvaerensis appears abruptly at 1378.87 m and immediately after the last record of *Pygodus anserinus* and *Amorphognathus inaequalis*. It ranges from the Kriaunos, through the Sartai and into the Vyžūnai formations. *Eoplacognathus elongatus* occurs together with *A. tvaerensis* from 1376.50 m to 1375.02 m. The *Amorphognathus tvaerensis* Zone extends up to the top of the investigated interval, where the fauna is represented by small non-diagnostic specimens of *Amorphognathus*.

The *Baltoniodus variabilis* Subzone is recorded from the base of the *Amorphognathus tvaerensis* Zone to the FAD of *Baltoniodus gerdae* at 1374.13 m. *Eoplacognathus elongatus* is constrained to this subzone. The FAD of *Baltoniodus gerdae* is at 1374.13 m and LAD is at 1372.31

m. The FAD of *B. gerdae* is abrupt and is associated with morphological changes of *Amorphognathus tvaerensis* holodontiform elements (Fig. 3Q, R). The change is closely tied with the Kriaunos and the Sartai formational boundary, marked by the prominent series of discontinuity surfaces. The *Baltoniodus alobatus* Subzone begins at 1371.13 m in the Šventupys Formation. *Baltoniodus alobatus* stratigraphically replaces *Baltoniodus gerdae* within the Sartai Formation and LAD of *Baltoniodus alobatus* is at 1370.05 m. The conodont fauna from the uppermost portion of the Šventupys Formation is low diverse and low yielding. Only few nondiagnostic conodonts have been recovered and the long-range genus *Panderodus* sp. is relatively the most frequent taxon.

The conodont succession recorded from the Bliudziai-150 core section is comparable with those previously known from Sweden (Bergström 1971, 2007), Estonia (Viira 2008, 2011; Viira *et al.* 2006; Hints *et al.* 2012), western Ukraine (Saadre *et al.* 2004) and Holy Cross Mountain, Poland (Dzik 1994).

The key chitinozoans and Baltoscandian Regional chronostratigraphy in the Bliudziai-150 core

LASNAMÄGI STAGE: Because the lower part of the Lasnamägi Stage consists of red-coloured carbonates, where organic matter is not preserved, no sampling was carried out here.

The grey limestone yielded the chitinozoan assemblage *Laufeldochitina striata*, *Tanuchitina tallinnensis*, *Cyathochitina sebyensis* and *Belonechitina pelliifera*, which are diagnostic for the Lasnamägi Stage.

UHAKU STAGE: The lower half of the Uhaku Stage is developed as red limestone without chitinozoans and other organic-walled microfossils. *Belonechitina pelliifera* can be a promising candidate for establishing the Lasnamägi/Uhaku stage boundary as the LAD of *B. pelliifera* has been recorded in the bed-by-bed sampled Uuga and Osmussaar sections of NW Estonia just below the boundary of this stage (Uuga cliff, Tammekänd *et al.* 2010, fig. 5; Osmussaar cliff, Hints *et al.* 2012, fig. 3). Characteristic of the late Uhaku Stage is the LAD of *Laufeldochitina striata* and the FAD of *Laufeldochitina stentor* in the next sample above (Nõlvak and Bauert 2006, appendix 9).

KUKRUSE STAGE: The Uhaku/Kukruse stage boundary was determined in the Bliudziai-150 drillcore by the FAD of *Eisenackitina rhenana*, which is suggested as a boundary index species by Hints *et al.* (2007). *E. rhenana*, *Belonechitina intonsa*, *Conochitina savalaensis*, *C. viruana*, *C. tigrina* and *Laufeldochitina* aff. *striata* are all known to occur in the sedimentary rocks of the Kukruse Stage of Baltoscandia. The well-defined, short-ranged chitinozoan species of the Kukruse age recorded in the Bliudziai-150 drillcore are *C. savalaensis*, *B. intonsa*, *C. viruana*, *L. aff. striata* and *C. tigrina*, while *E. rhenana* and *L. stentor* have been found in most samples of the Kukruse age.

A similar distribution pattern of key chitinozoan species can be seen in the studied Kerguta-565 and Savala drillcore sections in central and NE Estonia as well (Nõlvak & Bauert 2015, fig. 1).

HALJALA STAGE: The Kukruse/Haljala stage boundary is easily recognizable by the FAD of several new chitinozoan species in the early Haljala, including *Armoricochitina granulifera*,

Angochitina curvata and *Lagenochitina dalbyensis*. In addition to the short-ranged key chitinozoan species, *Cyathochitina giraffa* straddles the boundary interval. The key chitinozoan species *Belonechitina jaanussonii* and *B. hirsuta* are constrained to the Haljala Stage and can also be used to trace the Kukruse/Haljala stage boundary. The FAD of the key chitinozoan species *Spinachitina cervicornis*, *Desmochitina juglandiformis* and *D. nodosa* are restricted to the Haljala Stage. The *S. cervicornis* Zone extends to the Oandu Stage (Nölvak & Grahn 1993, fig. 6). However, the uppermost part of the studied section most likely belongs to the Haljala Stage.

In general the key chitinozoan species distribution in the Haljala Stage of the Bliudziai-150 drillcore matches well with reported data from Vasknarva-639, Piilsi-729 and Kerguta-565 drillcore sections in central Estonia (Bauert *et al.* 2014).

Correlation of chitinozoan and conodont zones

The ties of the chitinozoan and conodont successions from the Bliudziai-150 core is shown in Figure 1 and briefly outlined here. The *Laufeldochitina striata* chitinozoan Zone (Lasnamägi to Uhaku stages) comprises the *Pygodus serra* Zone and *Sagittodontina kielcensis* Subzone of the *Pygodus anserinus* Zone. The *Laufeldochitina stentor* Zone (uppermost Uhaku to uppermost Kukruse) initiates in the uppermost part of the *Pygodus anserinus* Zone and includes the *Baltoniodus variabilis* Subzone of the *Amorphognathus tvaerensis* Zone. The base of the Haljala Stage marks an onset of transgression in the Baltoscandian basin and the FAD of *Angochitina curvata*, *Armoricochitina granulifera* and *Lagenochitina dalbyensis* all from the Haljala Stage match with the appearance of *Baltoniodus gerdae* and the chitinozoan taxa are constrained to the *Baltoniodus gerdae* conodont Subzone. The younger *Belonechitina hirsuta* and *Spinachitina*

cervicornis zones are constrained to the *Baltoniodus alobatus* Subzone of the *Amorphognathus tvaerensis* Zone.

The chitinozoan and conodont biozones in the BI-150 core correspond to those already known from the Baltoscandian region and thus correlate easily with existing biostratigraphic chitinozoan and conodont zonations of the region (i.e. Bergström 1971, 1983, 2007a, b; Grahn and Nolvak 2010).

The Sandbian chitinozoan association from BI-150 has been recorded also from the Welsh and Shelve Inlier, UK (Vandebroucke 2008; Vandebroucke *et al.* 2009). International correlation of the conodont zones to e.g. South China, Precordilleran Argentina and eastern North America was outlined recently by Bergström (2007b).

The FAD of *Eisenackitina rhenana* is regarded an important proxy for the Upper Ordovician series boundary (and Darriwilian/Sandbian stage boundary) and was recorded at the base of global Upper Ordovician Series in the Fågelsång GSSP section, Sweden (Bergström *et al.* 2001; Vandebroucke 2004). In addition, *E. rhenana* was also recorded in several samples straddling the Middle to Upper Ordovician series boundary in the Lower Wood Brook and Spy Wood Brook sections of the Shelve Inlier, UK (Vandenbroucke *et al.* 2009), thus enabling a good biostratigraphic correlation of the lower Sandbian successions between Wales and Baltoscandia (see also Vandebroucke 2008). In the BI-150 core, *E. rhenana* appears at 1380.0 m within the *Laufeldochitina stentor* Zone. This level is placed within the *Amorphognathus inaequalis* conodont Subzone of the *Pygodus anserinus* Zone (Fig. 1), which is in accordance with the base of the international Upper Ordovician Series (or the Sandbian Stage) in the GSSP section at Fågelsång, Sweden (i.e. Bergström (2007a).

Summary

The common occurrence of chitinozons and conodonts from the detailed study of the BL-150 core are presented as collation of the two biozonations (Fig. 1). The chitinozoan and conodont successions in the BL-150 well, Lithuania, are nearly identical to those of previously described localities of the Baltocandian region (e.g. Hints *et al.* 2012). Conodonts allow correlation to the Mójca Limestone, Holy Cross Mountains, Poland (Dzik 1994), as well as to other localities worldwide (e.g. Bergström 2007b), while chitinozoans permit correlation to several localities in UK.

The appearance of several key chitinozoan species (*Armoricochitina granulifera*, *Angochitina curvata*, *Lagenochitina dalbyensis*) as well as the conodont species *Baltoniodus gerdae*, coincides closely with the Kukruse-Haljala regional stages boundary (1373.90 m) and represents the start of the Kegel depositional sequence (e.g. Dronov and Holmer 1999; Dronov and Rozhnov 2007). In the BL-150 well the first occurrence of *Eisenackitina rhenana* at 1380.00 m allows for the recognition of the base of the International Upper Ordovician Series (= Sandbian Stage) in carbonate facies.

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FIGURE CAPTIONS

Figure 1. The Ordovician succession of the BL-150 well and ranges of selected chitinozoan and conodont species for the upper Darriwilian – lower Sandbian succession. Inserted figure shows the Baltoscandian region and the location of the Bliudziai-150 well in southern Lithuania; the general outline of the ‘confacies belts’ (Jaanusson 1976) is indicated.

Figure 2. Illustration of selected chitinozoan species in the Bliudziai-150 core.

Dimensions (vesicle length x maximal diameter) are in μm . Scale bar is 100 μm for all images.

(A) *Laufeldochitina* aff. *striata*, GIT 726-1, sample 1376.35–1376.50 m, 1127x139. (B) *Tanuchitina tallinensis*, GIT 726-2, sample 1389.35–1389.54 m, 1023x103. (C) *Conochitina tigrina*, GIT 726-3, sample 1373.90–1374.19 m, 564x102. (D) *Belonechitina pellifera*, GIT 726-4, sample 1388.79–1389.00 m, 149x64. (E) *Belonechitina intonsa*, GIT 726-5, sample 1378.62–1378.87 m, 177x70. (F) *Desmochitina juglandiformis*, GIT 726-6, sample 1370.36–1370.59 m, 114x93. (G) *Angochitina curvata*, GIT 726-7, sample 1373.54–1373.90 m, 229x61. (H) *Armoricochitina granulifera*, GIT 726-8, sample 1373.54–1373.90 m, 232x118. (I) *Belonechitina jaanussonii*, GIT 726-9, sample 1372.51–1372.79 m, 368x81. (J) *Cyathochitina giraffa*, GIT 726-10, sample 1373.32–1373.54 m, 347x209.

Figure 3. Scanning microscope images of upper Middle and lower Upper Ordovician conodonts from the Bliudziai-150 core. Scale bars represent 100 μ m.

(A, B) *Baltoniodus prevariabilis* (Fåhræus). (A) Pa element, lateral view, sample 1390.92–1390.72 m, MGUH 32429. (B) Pb element, lateral view, sample 1390.92–1390.72 m, MGUH 31430. (C, D) *Baltoplacognathus reclinatus* (Fåhræus). (C) Sinistral pastiniplanate Pb element, upper view, sample 1389.54–1389.35 m, MGUH 31431. (D) Dextral stelliplanate Pa element, upper view, sample 1389.54–1389.35 m, MGUH 31432. (E, J, K, Q, R) *Amorphognathus tvaerensis* Bergström. (E) Pb element, outer lateral view, sample 1378.87–1378.62 m, MGUH 31433. (J) Pa element, upper view, sample 1378.87–1378.62 m, MGUH 31434. (K) Pb element, outer lateral view, sample 1378.87–1378.62 m, MGUH 31435. (Q) Geniculate (holodontiform) M element with large reclined cusp, lateral view, sample 1376.50–1376.35 m, MGUH 31436. (R) Geniculate (holodontiform) M element with large anterior denticles, sample 1376.50–1376.35 m, MGUH 31437. (F, G) *Baltoniodus variabilis* (Bergström). (F) Pa element, outer lateral view, sample 1378.87–1378.62 m, MGUH 31438. (G) Pa element, inner lateral view, sample 1378.87–1378.62

m, MGUH 31439. (**H, I**) *Baltoplacognathus robustus* (Bergström). (H) Dextral pastiniplanate Pb element, upper view, sample 1386.67–1386.50 m. MGUH 31440. (I) Dextral stelliplanate Pa element, upper view, sample 1385.17–1384.98m, MGUH 31441. (**L, M**) *Baltoniodus gerdae* (Bergström). (L) Pa element, outer view, sample 1373.08–1372.93 m, MGUH 31442. (M) Pb element, inner lateral view, sample 1373.08–1372.93 m, MGUH 31443. (**N–P**) *Eoplacognathus lindstroemi*. (N) Dextral pastiniplanate Pb element, upper view, sample 1383.15–1383.02 m, MGUH 31444. (O) Dextral stelliplanate Pa element, upper view, sample 1383.15–1383.02 m, MGUH 31445. (P) Sinistral stelliplanate Pa element, upper view, sample 1383.15–1383.02 m, MGUH 31446. (**S, T**) *Pygodus serra* (Hadding). (S) Pa (pygodiform) element, upper view, sample 1389.00–1388.79 m, MGUH 31447. (T) Pb (haddingodiform) element, lateral view, sample 1388.40–1388.12 m, MGUH 31448. (**U, V**) *Pygodus anserinus* Lamont and Lindström. (U) Pa (pygodiform) element, upper view, sample 1384.79–1384.55 m, MGUH 31449. (V) Pb (haddingodiform) element, lateral view, sample 1384.79–1384.55 m, MGUH 31450. (**X, Y**) *Eoplacognathus elongatus* (Bergström). (X) Dextral pastiniplanate Pb element, upper view, sample 1377.53–1377.43 m, MGUH 31451. (Y) Sinistral stelliplanate Pa element, upper view, sample 1377.53–1377.43 m, MGUH 31452. (**Z**) *Scabbardella altipes* (Hennigsmoen). Lateral view, sample 1379.37–1379.22 m, MGUH 31453.

Illustration of selected chitinozoan species in the Bliudziai-150 core.

Dimensions (vesicle length x maximal diameter) are in μm . Scale bar is 100 μm for all images.

(A) *Laufeldochitina* aff. *striata*, GIT 726-1, sample 1376.35–1376.50 m, 1127x139. (B) *Tanuchitina* *tallinensis*, GIT 726-2, sample 1389.35–1389.54 m, 1023x103. (C) *Conochitina* *tigrina*, GIT 726-3, sample 1373.90–1374.19 m, 564x102. (D) *Belonechitina* *pellifera*, GIT 726-4, sample 1388.79–1389.00 m, 149x64.

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117x76mm (300 x 300 DPI)

Scanning microscope images of upper Middle and lower Upper Ordovician conodonts from the Bludziai-150 core. Scale bars represent 100 μm .

(A, B) *Baltoniodus prevariabilis* (Fåhræus). (A) Pa element, lateral view, sample 1390.92–1390.72 m, MGUH 32429. (B) Pb element, lateral view, sample 1390.92–1390.72 m, MGUH 31430. (C, D) *Baltoplacognathus reclinatus* (Fåhræus). (C) Sinistral pastiniplanate Pb element, upper view, sample 1389.54–1389.35 m, MGUH 31431. (D) Dextral stelliplanate Pa element, upper view, sample 1389.54–1389.35 m, MGUH 31432. (E, J, K, Q, R) *Amorphognathus tvaerensis* Bergström. (E) Pb element, outer lateral view, sample 1378.87–1378.62 m, MGUH 31433. (J) Pa element, upper view, sample 1378.87–1378.62 m, MGUH 31434. (K) Pb element, outer lateral view, sample 1378.87–1378.62 m, MGUH 31435. (Q) Geniculate (holodontiform) M element with large reclined cusp, lateral view, sample 1376.50–1376.35 m, MGUH 31436. (R) Geniculate (holodontiform) M element with large anterior denticles, sample 1376.50–1376.35 m, MGUH 31437. (F, G) *Baltoniodus variabilis* (Bergström). (F) Pa element, outer lateral view, sample 1378.87–1378.62 m, MGUH 31438. (G) Pa element, inner lateral view, sample 1378.87–1378.62 m, MGUH 31439. (H, I) *Baltoplacognathus robustus* (Bergström). (H) Dextral pastiniplanate Pb element, upper view, sample 1386.67–1386.50 m, MGUH 31440. (I) Dextral stelliplanate Pa element, upper view, sample 1385.17–1384.98 m, MGUH 31441. (L, M) *Baltoniodus gerdæ* (Bergström). (L) Pa element, outer view, sample 1373.08–1372.93 m, MGUH 31442. (M) Pb element, inner lateral view, sample 1373.08–1372.93 m, MGUH 31443. (N–P) *Eoplacognathus lindstroemi*. (N) Dextral pastiniplanate Pb element, upper view, sample 1383.15–1383.02 m, MGUH 31444. (O) Dextral stelliplanate Pa element, upper view, sample 1383.15–1383.02 m, MGUH 31445. (P) Sinistral stelliplanate Pa element, upper view, sample 1383.15–1383.02 m, MGUH 31446. (S, T) *Pygodus serra* (Hadding). (S) Pa (pygodiform) element, upper view, sample 1389.00–1388.79 m, MGUH 31447. (T) Pb (haddingodiform) element, lateral view, sample 1388.40–1388.12 m, MGUH 31448. (U, V) *Pygodus anserinus* Lamont and Lindström. (U) Pa (pygodiform) element, upper view, sample 1384.79–1384.55 m, MGUH 31449. (V) Pb (haddingodiform) element, lateral view, sample 1384.79–1384.55 m, MGUH 31450. (X, Y) *Eoplacognathus elongatus* (Bergström). (X) Dextral pastiniplanate Pb element, upper view, sample 1377.53–1377.43 m, MGUH 31451. (Y) Sinistral stelliplanate Pa element, upper view, sample 1377.53–1377.43 m, MGUH 31452. (Z) *Scabbardella altipes* (Hennigsmoen). Lateral view, sample 1379.37–1379.22 m, MGUH 31453.

160x124mm (300 x 300 DPI)

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